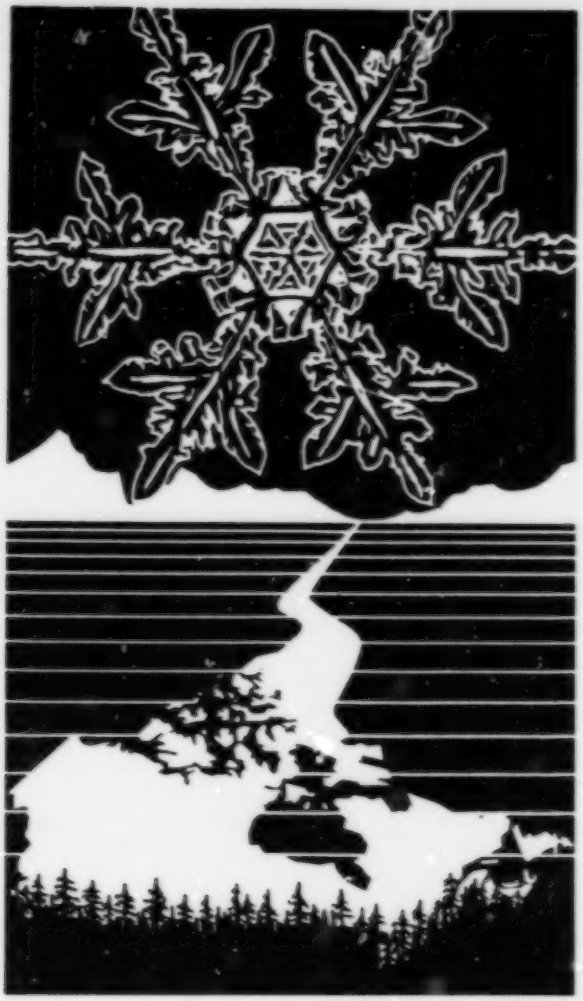

Environment Canada Environnement Canada

Northern Hydrology Symposium

JULY 10-12, 1990
SASKATOON, SASKATCHEWAN

Sponsored by:

National Hydrology Research Institute

Water Resources Division
Indian and Northern Affairs Canada

Canadian Water Resources Association

Committee of Regional Executives
Western and Northern Region
Environment Canada

Programme Enclosed

Abstracts

NORTHERN HYDROLOGY SYMPOSIUM PROGRAMME

Ramada Rennaissance, Saskatoon

(Paper sessions in Michelangelo "A" Room)

Monday, July 9

5:00 pm to 9:00 pm	**Registration**
7:00 pm to 9:00 pm	**Ice-Breaker** Venue: DaVinci Room, Ramada Renaissance Hotel Cash Bar, Complimentary Food Dress casual

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Tuesday, July 10

7:30 am to 5:30 pm	**Registration**
8:30 am to 8:40 am	**Symposium Opening** Dr. T.D. Prowse, Symposium Chairman
8:40 am to 8:50 am	**Welcome Address** Dr. T.M. Dick, Director National Hydrology Research Institute
8:50 am to 9:00 am	**Book Release** Northern Hydrology: Canadian Perspectives T.D. Prowse and C.S.L. Ommanney

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SESSION: BOOK CHAPTERS

9:00 am	Chairman: T.D. Prowse
9:00 am to 9:20 am	Snow Hydrology - P. Marsh
9:20 am to 9:40 am	Permafrost Hydrology - M.-K. Woo
9:40 am to 10:00 am	Ground-Water Hydrology - R. van Everdingen
10:00 am to 10:25 am	**COFFEE BREAK**

SESSION: BOOK CHAPTERS (cont.)

10:25 am to 10:30 am	Chairman: C.S.L. Ommanney
10:30 am to 10:50 am	Floating-Ice Hydrology - R. Gerard
10:50 am to 11:10 am	Glacier Hydrology - G.J. Young
11:10 am to 11:30 am	Water Quality - D. Gregor
11:30 am to 12:10 pm	Regional Hydrology - J. Wedel
12:10 pm to 1:25 pm	**LUNCH (Michelangelo "B")**

SESSION: INTERNATIONAL THEME PAPERS

1:25 pm to 1:30 pm	Chairman: T.D. Prowse
1:30 pm to 1:55 pm	Alaska - D.L. Kane
1:55 pm to 2:20 pm	China - Z. Yang
2:20 pm to 2:45 pm	Greenland - T. Thompsen
2:45 pm to 3:10 pm	Finland - E. Kuusisto
3:10 pm to 3:35 pm	**COFFEE BREAK**

SESSION: INTERNATIONAL THEME PAPERS (cont.)

3:35 pm to 3:40 pm	Chairman: C.S.L. Ommanney
3:40 pm to 4:05 pm	Norway - A. Killingtveit
4:05 pm to 4:30 pm	Sweden - L. Bengtsson
4:30 pm to 4:55 pm	U.S.S.R. - V. Grigoriev

DINNER **Venue: Bessborough Hotel, Riverside Gardens**

6:30 pm	Cash Bar Opens
7:00 pm	Barbeque Dinner

Wednesday, July 11

"ROGER J.E. BROWN" SESSION

(8:00 am to 5:30 pm	Registration - Tivoli Room)
8:45 am to 8:50 am	Chairman: M.-K. Woo
8:50 am to 9:10 am	Peatlands of the Lake Melville Coastal Plain, Labrador [30][1] - J.S. Price, D.A. Maloney and F.G. Downey
9:10 am to 9:30 am	Importance of Melting of Seasonal Frost to the Hydrology and Chemistry of a High Arctic Watershed on Axel Heiberg Island [11] - M. English, S. Schiff, M. Ecclestone, W.P. Adams, M. Hinton, L. Pezzutto, R. Elgood, C. Allan and D. Pierson
9:30 am to 9:50 am	River Icing Mounds: A Winter Water Source on the Eastern North Slope of Alaska [8] - B.F. Chacho, Jr., C.M. Collins, A.J. Delaney and S.A. Arcone
9:50 am to 10:10 am	A High Arctic Occurrence of Seasonal Frost Mounds [28] - W.H. Pollard
10:10 am to 10:35 am	**COFFEE BREAK**

"J. ARMAND BOMBARDIER" SESSION

10:35 am to 10:40 am	Chairman: P. Marsh
10:40 am to 11:00 am	Regional Snow Ablation in the Alaskan Arctic [17] - L.D. Hinzman, D.L. Kane and R.E. Gieck, Jr
11:00 am to 11:20 am	Areal Distribution of Snow Cover in Mountainous Areas [22] - A. Killingtveit and K. Sand
11:20 am to 11:40 am	Hydrological Processes in a Small Catchment Containing a Perennial Snowbank, Melville Island, N.W.T. [25] - A.G. Lewkowicz and K.L. Young
11:40 am to 12:00 pm	Relationship Between Snow Chemistry and Blowing Snow: Initial Findings [29] - J.W. Pomeroy, T.D. Davies and M. Tranter
12:00 pm to 1:25 pm	**LUNCH (Michelangelo "B")**

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[1] Reference number for abstracts

"HOWARD T. BARNES" SESSION

1:25 pm to 1:30 pm	Chairman: R. Gerard
1:30 pm to 1:50 pm	Case Study of a Grounded Jam; Restigouche River, N.B. [1] - S. Beltaos and B.C. Burrell
1:50 pm to 2:10 pm	Preliminary Findings on Formation and Evolution of Frazil and Anchor-Ice Under Laboratory Conditions [34] - G. Tsang and B. Trapp
2:10 pm to 2:30 pm	Longitudinal Dispersion in the Ice-Covered Athabasca River [35] - G. van der Vinne and D. Andres
2:30 pm to 2:50 pm	A Physical Model of Ice Overthrust During the Break-Up of Intact River-Ice Covers [10] - M.N. Demuth and T.D. Prowse
2:50 pm to 3:10 pm	On Computer Simulation of Ice Motion in Rivers [37] - O. Vinogradov, A. Springer and P. Wierzba
3:10 pm to 3:35 pm	**COFFEE BREAK**

"FATHER THOMAS O'D. HANLEY, S.J." SESSION

3:35 pm to 3:40 pm	Chairman: J. Wedel
3:40 pm to 4:00 pm	Economic Impact of River Ice Jams in Canada [36] - G. van der Vinne, T.D. Prowse and D. Andres
4:00 pm to 4:20 pm	Ice Cover Growth and Freeze-out of Solutes in a Mackenzie Delta Lake [24] - L.F.W. Lesack, P. Marsh and R.E. Hecky
4:20 pm to 4:40 pm	Interactive Modelling of Cold-Regions Watersheds with SSARR [7] - E.A. Cassell and T.J. Pangburn
4:40 pm to 5:00 pm	A Basin Water Storage Model to Forecast Columbia River Discharge [33] - W. Tangborn

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BANQUET **Venue: Ramada Renaissance, Michelangelo "B" Room**

6:30 pm	Cash Bar Opens
7:00 pm	Banquet
Speaker:	Dr. E.F. Roots - Reflections on the Hydrological Response to Climate Changes in High Latitudes

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Thursday, July, 13

"FRITZ MÜLLER" SESSION

(8:00 am to 5:30 pm	Registration - Tivoli Room)
8:45 am to 8:50 am	Chairman: G.J. Young
8:50 am to 9:10 am	Drainage of an Ice-Dammed Lake, Kaskawulsh Glacier Basin, Yukon [21] - J.N. Kasper and P.G. Johnson
9:10 am to 9:30 am	The Shape, Length and Flow Conditions of Conduits at South Cascade Glacier, Washington State, U.S.A. [12] - A.G. Fountain
9:30 am to 9:50 am	Discharge Regimes of a Glacierized Basin, Slims River, Yukon [19] - P.G. Johnson
9:50 am to 10:10 am	On Modelling Surface Meltwater Run-Off From Arctic and Alpine Glaciers [27] - D.S. Munro
10:10 am to 10:35 am	**COFFEE BREAK**

"SIR CHARLES WRIGHT" SESSION

10:35 am to 10:40 am	Chairman: G.J. Young
10:40 am to 11:00 am	Estimation of Mass Balance and Run-Off Component of Urumqi Glacier No.1 From Water Balance Analysis [38] - Yang Zhenniang
11:00 am to 11:20 am	Pulses in Glacier Discharge: Indicators of the Internal Drainage System of Glaciers [20] - P.G. Johnson
11:20 am to 11:40 am	Water Storage in Alpine Glaciers [4] - M. Brugman
11:40 am to 12:00 pm	Simulation of Run-off in High and Cold Mountainous Regions [39] - Yang Zhihuain
12:00 pm to 1:10 pm	**LUNCH (Michelangelo "B")**

"DON A. GILL" SESSION

1:10 pm to 1:15 pm	Chairman: D. Gregor
1:15 pm to 1:35 pm	Water Balance and Geochemistry Studies in a Tundra Watershed: District of Keewatin, Northwest Territories [6] - G.G. Bursey, T.W.D. Edwards and S.K. Frape
1:35 pm to 1:55 pm	Hydrogeochemical Aspects of Two Selected Sites in a Fringe Zone of Discontinuous Permafrost and Their Implications [23] - Y.T.J. Kwong, D. Craig and M. Griffin
1:55 pm to 2:15 pm	CO_2-Rich Groundwaters of the Flat River Valley, N.W.T. [15] - S.M. Hamilton and F.A. Michel
2:15 pm to 2:35 pm	Geochemical Evolution of Water in a Continental High Boreal Wetland: Preliminary Results [9] - D. Craig
2:35 pm to 2:55 pm	Origin of Acidity in Colour Lake, Axel Heiberg Island (79°25'N) [31] - S. Schiff, M. English, R. Elgood, M. Hinton, M. Ecclestone and L. Pezzutto
2:55 pm to 3:20 pm	COFFEE BREAK

"DONALD S. RAWSON" SESSION

3:20 pm to 3:25 pm	Chairman: D. Lawson
3:25 pm to 3:45 pm	Modelling Oxygen Regime of Northern Rivers Under the Conditions of Human Impact [3] - V.F. Brekhovskikh and Yu.G. Volpian
3:45 pm to 4:05 pm	Transformation of Heavy Metals by Tidal Flows in the Severnaya Dvina River Estuary [2] - V.F. Brekhovskikh, A.N. Malutin and M.A. Mordasov
4:05 pm to 4:25 pm	Estimates of Evaporation in the Yukon Territory and the Northwest Territories -- Alternative Method and Assessment of the Effect of Climate Change [14] - J. Haas
4:25 pm to 4:45 pm	Yukon and N.W.T. Ground-water Data Base [16] - P. Hardisty, V. Schilder, T. Dabrowski and J. Wells
4:45 pm to 5:05 pm	Regionalization of Lov Flows in Yukon Territory [18] - J.R. Janowicz
5:05 pm to 5:15 pm	Closing Remarks

A B S T R A C T S

[2]. TRANSFORMATION OF HEAVY METALS BY TIDAL FLOWS IN THE SEVERNAYA DVINA RIVER ESTUARY

by
V.F. Brekhovskikh, A.N. Malutin and M.A. Mordasov[1]

Heavy metals (HM) are one of the most dangerous pollutants brought by river flow into the sea. Even if their concentration in the water is small, they can be toxic for biota. Biogeochemical behaviour and toxicity of HM in aquatic ecosystems are usually determined by the variety of forms of their occurrence in the aquatic medium. In estuarine systems the most significant transformations of HM is in the river and sea water mixing zone, due to intensified hydrodynamic and hydrological processes in this zone.

Experimental studies were carried out in the Severnaya Dvina estuary; one with complex turbulent water circulation. High concentration of humic substances (HS) in river water subject to tidal flows has the most significant effect on the sedimentation of microelements transported by the river water.

Al, Fe, Mn, Cu, Zn, Ni in the solution were determined using complex analysis, including membrane filtration, sorptional concentration on ion-exchange cellulose and atomic emission spectroscopy with inductively coupled plasma. It allowed us to determine:

I. ionic and inorganic forms of HM;
II. complex compounds HM + organic base;
III. HM forms connected with HS (complex compounds of heavy metals with humic and fulvic acids and organic-mineral colloids).

The concentrations of humic acid (HA) and fulvic acid (FA) in water samples were determined using a spectrophotometric method with preliminary separation and concentration on DEAEA-cellulose. Results singled out 3 specific zones in the Severnaya Dvina estuary. Zone (I) a river reach characterized by inconsiderable variations of the water salinity (0 - 0.1‰) and a sharp fall of total HM content in the solution (342.0 - 195.0 $\mu g \cdot L^{-1}$). Zone (II) the delta area of the river, where further increase in the salinity (up to 1.3‰) is observed; HA concentration is 1.06 - 0.90 $\mu g \cdot C \cdot L^{-1}$, FA is 5.92 - 3.04 $\mu g \cdot C \cdot L^{-1}$, total HM content falls to 82.0 $\mu g \cdot L^{-1}$. Zone (III) the frontier zone characterized by a sharp (up to 9.5‰) growth of salinity and considerable fall of HA and FA concentrations (0 and 0.2 $\mu g \cdot C \cdot L^{-1}$, respectively); total HM content in the solution falls to 30.0 $\mu g \cdot L^{-1}$.

The following empirical equations describe the dependence of HA and FA content in the estuarine waters on their salinity:

$$C_{HA} = 1.37e^{-0.135\,S} \qquad C_{FA} = 5.40e^{-0.285\,S}$$

Here C_{HA} and C_{FA} are concentrations of humic and fulvic acids, respectively, and S is the salinity of estuarine water.

On the one hand, in a process of HA and FA sedimentation in the estuary, 33.7% of Al, 88.2% of Fe, 40.7% of Mn, 85.8% of Cu, 88.0% of Zn and 80.0% of Ni are sedimented to the bottom from the solution. On the other hand, a stable tendency to the increase in the concentration of inorganic and ionic forms of Mn, Cu, Zn, Ni is observed, which is explained by their transport from the bottom sediment and suspension, as well as by the dissociation of complex HM compounds with dissolved organic substances. The dissociation takes place in the estuarine bottom sediment due to the competing effects of Ca^{2+} and Mg^{2+} cations, on the one hand, and seawater on the other.

[1]Water Problems Institute of the U.S.S.R. Academy of Sciences, 13/3 Sadovo-Chernogriazskaya, 103064 Moscow, U.S.S.R.

[3]. MODELLING OXYGEN REGIME OF NORTHERN RIVERS UNDER THE CONDITIONS OF HUMAN IMPACT

by
V.F. Brekhovskikh and Yu.G. Volpian[1]

Dissolved oxygen (DO) and readily-oxidized organic matter are very important water-quality indices, reflecting the degree of human impact on water bodies.

This paper presents the dynamics of labile organic matter and DO in the Sukhona River during the summer (July) and winter (March) dry periods. The work is based on in situ observations carried out by the researchers of the Water Problems Institute (the U.S.S.R. Academy of Sciences) and the Division of Hydrometeorological Service and Environment Control.

In order to determine DO and organic-matter concentration in the water, a system of ordinary differential equations, describing the dynamics of BOD and DO deficit, was solved. A modification of the Streeter-Phelps model was used as a basic one, taking into account hydraulic characteristics of the river:

$$V \cdot \frac{dY_1}{dx} = -(K_1 + K_3)\, Y_1 + la \qquad Y_1(0) = Y_1^{\circ}$$

at

$$V \cdot \frac{dY_2}{dx} = -K_1 Y_1 - K_2 Y_2 + R_6 \qquad Y_2(0) = Y_2^{\circ}$$

where Y_1 = BOD concentration ($mg \cdot L^{-1}$); $Y_2(C_s - C)$ = DO deficit ($mg \cdot L^{-1}$; C is real/actual O_2 concentration; C_s is saturated one); la = additional input of organic matter ($mg \cdot L^{-1} \cdot d^{-1}$); R_6 = rate of oxygen assumption by bottom sediment ($mg \cdot L^{-1} \cdot d^{-1}$); x, V, H, are hydraulic characteristics of the river; x = the distance from river source (km); V = flow velocity ($km \cdot d^{-1}$); H = depth (m); K_1 = coefficient of biochemical oxidation (d^{-1}); K_2 = coefficient of aeration (d^{-1}); K_3 = coefficient of organic matter sedimentation (d^{-1}).

The main approximations, adopted in the model, are as follows:

- the flow is steady;
- the longitudinal dispersion of the pollutant is neglected;
- biochemical oxidation of the labile organic matter occurs as the reaction of the first order;
- basic oxygen input is connected with the aeration (photosynthesis is neglected or absent);
- aeration rate is proportional to DO deficit;
- concentration of the saturation in O_2 depends only on water temperature;
- diurnal variations of water temperature and solar radiation are neglected.

Model coefficients are assigned for the hydraulic characteristics of the river:

$$K_1 = K_1^{\circ} + x \frac{V}{H} \qquad \text{for} \qquad V = 0.1 - 0.5\ m \cdot s^{-1}$$

$$K_2 = \begin{cases} aV^{0.5} / H^{1.5} \\ bV \quad / H^{1.67} \end{cases} \qquad \text{for} \qquad V = 0.5 - 2.0\ m \cdot s^{-1},\ H > 1.0\ m$$

Here K_1, x, a, b are parameters depending on the type of the river bottom and water temperature; K_2 is selected especially for the hydraulic characteristics of the Sukhona River.

The 540-km long river reach was divided into intervals $\Delta X = 20$ km. Under this condition the numeric realization of the model required the solution of 52 differential equations and took 5 seconds computer time (IBM-PC-AT). A four-stage method of Runge-Rutt served as the calculation algorithm.

The results allowed us to describe the actual distribution of the DO deficit along the river channel during both summer and winter dry periods. In the first case the model curve has a characteristic maximum (at X ~ 60 km) in the Pel'shna region, which corresponds to the measurement data. In the second case the model curve has a steady growth, connected with the absence of aeration in winter and possible decrease in DO concentration due to oxidation of wood debris at the bottom of the river.

[1]Water Problems Institute of the U.S.S.R. Academy of Sciences, 13/3 Sadovo-Chernogriazskaya, 103064 Moscow, U.S.S.R.

[4]. WATER STORAGE IN ALPINE GLACIERS

by
Melinda M. Brugman[1]

Liquid water is temporarily stored within an alpine glacier and modifies the pattern of terminus stream discharge (Tangborn, Krimmel and Meier, 1975). The release of glacially-derived water can maintain river discharge from glacierized areas during critical periods such as late summer and years that are unusually warm and dry (Young, 1977, 1978). The goal of this study is to increase the accuracy of run-off models from glacierized northern regions. In this paper, the issue of water storage within a glacier is examined using a simple model derived from direct observations. These include measurements of snow accumulation and meltwater production, tracer advection and dispersion, stream discharge and conductivity, and ice volume change. Evidence of long-term (seasonal) glacier water storage is contrasted to that of short-term (daily) meltwater production and run-off.

Glaciers examined include four non-surge type glaciers, a glacier showing some degree of flow instability and a surge-type glacier. The glaciers compared in this study are located in western North America and in the European Alps. Surface ablation and stream discharge data are used to analyse the relative importance between the release of glacially-stored water versus the enhanced melting of surface snow and ice. Dye tracing, turbidity and conductivity data are used to examine the relative importance between water storage at the surface, within the glacier and at the bed of the glacier. The problem of characterizing englacial as compared to basal water storage is discussed and data evaluated. Water storage is modelled for stagnant zones located along the length of an arborescent subglacial water channel, and is evaluated with dye dispersion data obtained by the author and others. Glacier mass balance and ice volume changes are contrasted for several basins in order to evaluate the accuracy of water storage predictions and run-off models.

Water storage within a glacier is maximum when the glacier is covered with a deep wet snowpack and the glacier flow velocities are very high. For

the first case, if the snowpack is thick, then a great amount of surface melt may be stored within the intergranular void space. The total amount of water that may be stored within this surface "sponge" zone is further increased when a deep firn-pack exists, as measured by the integrated glacier mass balance over several decades. When glacier sliding velocities are high (such as during early summer or a glacier surge), basal cavities may enlarge and store great volumes of water at (or near) the glacier bed. The rate of water flow through a glacier is reduced at times of high ice flow rates because the higher glacier shear-strain rates accelerate closure of subglacial and englacial water channels. The stored basal water is released either when the cavities collapse or a mature arborescent drainage system eventually develops.

Results indicate glacier water storage and release behaviour, as well as ice accumulation and meltwater production rates, are determined by snow and firn depths, near-surface porosity and permeability, glacier albedo and roughness, extent and depth of crevassing; water storage is further determined by maturity of glacier water drainage systems, subglacial bed permeability, basal rheology and glacier flow behaviour. Recent ice-volume change surveys suggest that more meltwater is produced within a glacier that is measured using standard glacier mass balance techniques (as described by Østrem and Stanley, 1965). Hydrological models of long-term water storage in glaciers must be re-examined using more complete measurements of glacier ice volume change, mass balance and meltwater production within a glacier.

[1]National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, S7N 3H5

[5]. SNOWMELT INFILTRATION INTO FROZEN SOIL AT SITES IN THE DISCONTINUOUS PERMAFROST ZONE NEAR MAYO, YUKON TERRITORY

by
C.R. Burn[1]

The near-surface ground thermal and hydrological regimes of four sites near Mayo, central Yukon, were monitored during spring 1985 and 1988 to determine: snowmelt infiltration in absolute terms and as a fraction of snowpack water equivalent; frost heave accompanying snowmelt infiltration; and soil warming associated with infiltration. Infiltration was monitored via neutron probe; frost heave was measured with telescoping heave tubes and magnets; soil temperatures were determined with thermistors.

Between 10 and 70 per cent of the snowpack infiltrated the soil at the sites studied. Maximum infiltration was recorded where soils were dry during the preceding fall. Little heave accompanied infiltration: snowmelt occupied soil pore space rather than contributing to ice-lens growth. At dry sites, most infiltration was driven by gravity rather than the soil temperature gradient, but at sites which were saturated during the preceding fall, infiltration was temperature-induced. Ground temperatures increased during snowmelt to depths of up to 3 m. The increase in temperature was due to sensible heat transfer by the infiltrating water rather than refreezing.

[1]Department of Geography, University of British Columbia, Vancouver, B.C., V6T 1W5

[6]. WATER BALANCE AND GEOCHEMISTRY STUDIES IN A TUNDRA WATERSHED: DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

by
G. Glenn Bursey, T.W.D. Edwards and S.K. Frape[1]

Results are reported from hydrological field studies in the summers of 1988 and 1989 in a tundra watershed in the eastern Arctic. Investigation of the water cycle in terrain underlain by continuous permafrost is being conducted using isotopic and geochemical data from precipitation, surface water, and active-layer ground water, coupled with hydrogeological and hydrological field observations.

Water-balance calculations based primarily on isotopic data ($^{18}O/^{16}O$ and $^{2}H/^{1}H$ ratios) indicate wide variation in the degree of evaporation from various levels in the drainage system. Evaporation can account for 40% or more of annual discharge from shallow tundra ponds, whereas average annual vapour discharge from the entire watershed is likely about 10%, in spite of the arid low-arctic climate. Evaporative losses are minimized in part by the relative importance of subsurface storage and flow within the active layer.

Surface and subsurface waters are characterized by extremely low solute concentrations and are undersaturated with respect to most mineral phases, excepting the amorphous forms of silica and $Fe(OH)_3$. High iron contents (up to 38 $mg \cdot L^{-1}$) in some ground-water samples may stem from complexing with dissolved organic carbon. Other processes such as cation exchange and freezing influence the chemistry of ground-waters within the active layer.

[1]Waterloo Centre for Groundwater Research, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, N2L 3G1

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[7]. INTERACTIVE MODELLING OF COLD-REGIONS WATERSHEDS WITH SSARR

by
E. Alan Cassell[1] and Timothy J. Pangburn[2]

SSARR (Synthetic Streamflow and Reservoir Regulation) is a generalized watershed model for computing run-off from rainfall and/or snowmelt events. The Corps of Engineers developed SSARR to simulate watershed systems for the planning, design and operation of water-control projects and is presently used in many countries throughout the world.

SSARR was originally programmed in FORTRAN and used with mainframe computers. Certain of the capabilities of SSARR recently have been adapted to the PC environment. However, the use of SSARR remains relatively difficult and time consuming. This paper reports on work in which SSARR was reprogrammed into STELLA, an object-oriented programming environment that uses finite-difference methods on Macintosh computers for simulation, calibration and sensitivity analyses. The resulting model, SSARR-DS allows many of the capabilities of SSARR to be used in a user-friendly interactive environment. Output from the SSARR-DS model can be graphical or tabular.

The underlying model equations are easily printed for review. The structure of the model is easily modified to meet different watershed conditions. Model parameters are easily adjusted, data are conveniently input and run-off simulations are calculated and rapidly displayed. Thus, operational simulations, model calibration and sensitivity analyses are rapidly accomplished in a workstation environment.

This paper will discuss the STELLA programming framework, the basis for the SSARR-DS model and the input parameters to the model. SSARR-DS was calibrated using hydrometeorological data from the Sleepers River Cold Regions Research Watershed located in Northeastern Vermont, U.S.A. Calibration and extensive exercises will be discussed. A wide variety of cold-regions hydrometeorological conditions including winter and spring melt conditions were evaluated. The potential for improvement of stream forecasting by incorporating into SSARR-DS such parameters as water-temperature data, considerations of run-off on frozen ground and rain-on-snow will be presented. The potential for this dynamic model to be integrated with spatially variable parameters through GIS technology is briefly discussed.

The SSARR-DS model provided excellent run-off simulations and, when considered in combination with it's ease of use, SSARR-DS has the potential to become a useful operational tool for cold-regions hydrology.

[1]School of Natural Resources, University of Vermont, Burlington, VT 05405, U.S.A.

[2]Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers, Hanover, New Hampshire, U.S.A.

[8]. RIVER ICING MOUNDS: A WINTER WATER SOURCE ON THE EASTERN NORTH SLOPE OF ALASKA

by

E.F. Chacho, Jr, C.M. Collins, A.J. Delaney and S.A. Arcone[1]

The icing mounds on two eastern North Slope river systems were investigated in April 1989. Approximately 100 mounds were surveyed on each river, representing about half the total number. The surveys were conducted using an airborne short-pulse radar system, from which water-bearing mounds could be distinguished from dry mounds and estimates of ice thickness and mound height could be made for most of the icing mounds. The distribution of icing mounds was measured on a 70 km reach of each river, extending from their coast to the Sadlerochit Mountains. An ice thickness of 1.3 - 1.5 m separated water-bearing and dry mounds, while a mound height of 1.25 m was found to be a useful parameter for identifying water-bearing mounds.

[1]U.S. Army Cold Regions Research and Engineering Laboratory, Fairbanks, Alaska and Hanover, New Hampshire, U.S.A.

[9]. GEOCHEMICAL EVOLUTION OF WATER IN A CONTINENTAL HIGH BOREAL WETLAND: PRELIMINARY RESULTS

by
D. Craig[1]

A study of the geochemical evolution of water in the Manners Creek watershed near Fort Simpson, N.W.T., has been underway since June 1989. The watershed is felt to be typical of the large wetland basins that cover large segments of that region. Preliminary sampling of water chemistry and sediment stratigraphy and mineralogy has been carried out. The chemistry of shallow ground water, as well as water in the active layer, in the wetland, and in the stream draining the wetland has been examined. Water chemistry within the basin is dominated by the weathering of calcite and dolomite and water in the basin can be classified as Ca^{2+} - HCO_3^- water. Shallow ground waters in the lower river valley of the basin have elevated levels of dissolved sulfate due to weathering of gypsum found in the lower clay unit. During the spring melt period of 1990 a significant concentration of calcium, magnesium, and alkalinity was observed in the basin run-off. It is hypothesized that vertical (upward) transport processes in the unsaturated zone, probably driven by evapotranspiration, are important in moving carbonates to the surficial layer of sphagnum, where they are readily available for weathering during the spring snowmelt period. It is felt that shallow active layer flow is the predominant process generating run-off during the spring 1990 run-off period.

[1]National Hydrology Research Institute, Environment Canada, Saskatoon, Saskatchewan, S7N 3H5

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[10]. A PHYSICAL MODEL OF ICE OVERTHRUST DURING THE BREAK-UP OF INTACT RIVER-ICE COVERS

by
M.N. Demuth and T.D. Prowse[1]

The passage of water surges resulting from ice-jam releases or spring run-off events can lead to the fracture of intact ice covers, ice runs and further jamming downstream. The nature of the fracturing and clearance processes plays an important role in the likelihood and severity of ice jamming. To date much effort has concentrated on the treatment of ice accumulation dynamics and jam stability, however characterizing the processes by which the initial cover fractures has received limited attention. This paper discusses and illustrates a simple model of ice plate overthrusting fracture, a process commonly observed during river-ice break-up. The role of natural flaws and cover variability in the precipitation of fracture fronts is addressed.

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[11]. IMPORTANCE OF MELTING OF SEASONAL FROST TO THE HYDROLOGY AND CHEMISTRY OF A HIGH ARCTIC WATERSHED ON AXEL HEIBERG ISLAND (79°25'N)

by

M. English[1], S. Schiff[2], M. Ecclestone[3], W. P. Adams[3], M. Hinton[2], L. Pezzutto[1], R. Elgood[1], C. Allan[3], D. Pierson[3]

High arctic watersheds are amongst the most sensitive systems to change resulting from global warming due to expected exaggerated amplitude of temperature change in the Arctic and the presence of permafrost at shallow depths in the soils. Colour Lake watershed is located in the High Arctic on Axel Heiberg Island and has been the object of research on the hydrogeology of high-arctic systems for several years. The watershed is small, 80 ha in area, and contains a small lake (10 ha) with an exceptionally low pH of 3.7. Sampling was conducted during springmelt, in late summer and early fall from 1985 - 1989 in order to examine seasonal differences in water and dissolved ion contribution to the lake. The lake hydrological mass balance was constructed by gauging lake inflows and outflow and by installing a series of small ground-water piezometers. Soils and lake sediments were collected for permeameter studies to assess: 1) hydraulic conductivities and 2) dissolved ion concentration of infloving water. Measurements of $\delta^{18}O$ in lake stream, precipitation and ground water are used to verify the mass balance and to ascertain the fraction of snowmelt water entering the lake that does not mix with the lake but is diverted directly to the lake outflow. Preliminary calculations show that the springmelt is much less important in terms of both the hydrological and chemical mass budgets of the lake than the subsequent melting of water contained in the seasonally-frozen (active) layer. This result is due to several factors; the low amount of yearly precipitation that accumulates as snow in the basin, the limited interaction of snowmelt with the underlying soils due to frozen soils during the snowmelt period, the large amount of water contained in the active layer and the high chemical reactivity of soils contained in this active layer. Global warming will increase the thickness of the active layer, increasing the contribution of soil water to the hydrological and chemical budgets of high-arctic systems and will expose previously unweathered soils to water contact. This effect will be discussed in light of the hydrogeological and chemical data collected at the Colour Lake catchment.

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[12]. THE SHAPE, LENGTH, AND FLOW CONDITIONS OF CONDUITS AT SOUTH CASCADE GLACIER, WASHINGTON STATE, U.S.A.

by
Andrew G. Fountain[1]

The hydraulic properties of the subglacial drainage system of South Cascade Glacier are inferred by examining how discharges of water, solutes, and artificial tracers in streams draining the glacier respond to water input from surface melt and precipitation. Results from the injection of tracers, corroborated by water budget calculations, indicate that South Cascade Glacier is divided into two main basins. Each basin is drained by a single stream. Drainage divides exist on the glacier surface and at the bed, but their positions may not always coincide. Time of travel and dispersion tracers also are significantly different in each basin.

It is hypothesized that one stream drains from an isolated conduit and daily meltwater in the ablation zone reaches the conduit directly through englacial channels. The other stream drains a conduit that is supplied by water flowing from a distributed network of small interconnected conduits probably at the interface between the ice and subglacial debris.

The cross-sectional geometry and sinuosity of the isolated conduit has been inferred by analyzing the dispersion and travel time of tracers. The dispersion is thought to result from the velocity shear in the conduit and based on the travel time of the initial tracer concentration and peak concentration the flow depth is calculated. The width of the conduit, determined from the measured value of the discharge and calculations of flow depth and velocity, are very broad relative to the depth and are quite sinuous. The width and sinuosity increase during periods of high discharge. Comparing the slope of the logarithm of travel time versus the logarithm of water discharge for measured values to the slope of theoretical values based on Manning's equation, it is inferred that the conduit was probably pressurized in mid-summer, during maximum ice melt, but then changed to open conduit flow when discharge decreased.

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[13]. COMPARATIVE STUDY OF WATER QUALITY IN SMALL RIVERS, BASED ON PERIPHYTON INDICES

by
E.A. Goncharevich[1]

This paper is devoted to the study of periphyton in the Moskva River tributaries. Data obtained on the qualitative composition of periphyton allows for comparison of the water quality of thes tributaries using saprobility indices and a method of desirability function.

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[14]. ESTIMATES OF EVAPORATION IN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES -- ALTERNATIVE METHOD AND ASSESSMENT OF THE EFFECT OF CLIMATE CHANGE

by
Jiri Haas[1]

This paper examines the water-balance equation for fourteen selected river basins in the Yukon Territory and the Northwest Territories as well as the impact of climate change on the components of the water-balance equation. The evaporation/evapotranspiration component of the water-balance equation is studied in more detail using the complementary relationship evapotranspiration model. Alternative evaporation/evapotranspiration results are used for the calculation of water balance. The results show decreasing trends in water storage. The water balance is then modified for alternative ('after-the-climate-change') values of evaporation/evapotranspiration and precipitation; the results indicate the possibility of changes in water storage and run-off.

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[15]. CO_2-RICH GROUNDWATERS OF THE FLAT RIVER VALLEY, N.W.T.

by
S.M. Hamilton and F.A. Michel[1]

A series of CO_2-rich (>1 atm. pCO_2) travertine-depositing cold springs were identified discharging along the western margin of the Flat River valley during a hydrogeologic investigation of springs in a portion of the Ragged Ranges adjacent to Nahanni National Park, N.W.T.

The chemistry of the springs is dominated by Ca^{2+}, Mg^{2+} and HCO_3^- with large quantities of gaseous CO_2 bubbling in all vents. pH values range between 5.9 and 6.3, while water temperatures vary between 1.6 and 8.9°C. $\delta^{13}C$ values for dissolved inorganic carbonate (-0.4 to +3.9‰) indicate that

the CO_2 may be derived from metamorphic reactions at depth. Oxygen and hydrogen stable-isotope data from these spring waters suggest a meteoric origin, while the presence of tritium implies a relatively short subsurface residence time.

A model is presented where a separate CO_2-rich fluid, generated through metamorphic reactions at depth, rises along a structural lineament and mixes with shallow circulating ground water prior to discharge within the valley.

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[16]. YUKON AND N.W.T. GROUND-WATER DATA BASE

by

Paul Hardisty[1], Vlado Schilder[2], Tadeuz Dabrowski[1] and Joseph Wells[3]

Recognizing the importance of ground water to the Canadian North, and the need to foster and protect this valuable resource for the future, the Department of Indian and Northern Affairs has sponsored development of a ground-water data base for the Yukon and N.W.T. No such system for collecting and archiving hydrogeological data from the Territories existed before initiation of this project.

The data base is designed for IBM-compatible PC's, and is based on dBase IV software. Data from each well, piezometer or spring are divided into sections on general information (location, name), aquifer characteristics (pump test data, water levels), well completion (depth, screen location), geology (drilling log, permafrost data), and water quality (main ions, metals, organics, trace organics, and bacteriological parameters). The data base has specific slots for over 280 hydrogeological parameters, and large comment fields for additional information.

As part of the project, approximately 35,000 pieces of hydrogeological data for the Yukon and N.W.T., representing about 1200 wells, borenoles and springs, were collected from various sources throughout Canada. Most of these data have now been screened, rated for quality, and input into the data base. New data are being collected as they become available. Data files on diskette are available from DIAND upon request, however DIAND maintains control over data-file modification and input. Data files can be accessed and reports generated by other users with Relational Report Writer software.

It is anticipated that the data base will prove to be a useful tool in such areas as regulatory control, ground-water exploration, protection and contamination investigations, and regional and local hydrogeological studies.

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[17]. REGIONAL SNOW ABLATION IN THE ALASKAN ARCTIC

by

Larry D. Hinzman, Douglas L. Kane and Robert E. Gieck, Jr[1]

The rates of snowpack ablation were monitored at three sites in Northern Alaska for three years in a transect from the Brooks Range to the Arctic Coastal Plain. These data were analysed along with intensive meteorological data collected at each site. The initiation of ablation was site-specific being largely controlled by the complementary addition of energy from radiation and sensible heat flux. Although they were only 115 km apart, the rates and mechanisms of snowmelt varied greatly. Snowmelt begins at the mid-elevations in the Foothills and progresses northerly towards the coast and southerly up into the mountains. In the more southerly sites, snowpack ablation progressed much faster when compared to the northerly site. The southerly sites are much more influenced by the sensible heat advected from areas south of the Brooks Range. A comparison of the measured energy balances reflected the increasing importance of net radiation in the more northerly site.

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[18]. REGIONALIZATION OF LOW FLOWS IN YUKON TERRITORY

by

J.R. Janowicz[1]

There is an increasing demand for low flow information for water management purposes in northern regions. The emphasis to date has been on the estimation of peak flows; however, it is now apparent that low flows are often the limiting factor in many water-use applications. A methodology for estimating 7-day low flows for ungauged streams through Yukon Territory was developed. The Territory was separated into four regions of homogeneous low flow response based on the analysis of various low-flow parameters. Low flows generally decrease with increasing latitude and distance from the moderating effects of the Pacific Ocean. This trend is largely controlled by the distribution of permafrost which influences ground-water contributions to winter streamflow. Temperature distribution was found to be a good indicator of the relative influence of the underlying permafrost on hydrological response. Functional relationships were developed between 7-day low discharge at selected return periods and physical basin and climatic parameters.

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[19]. DISCHARGE REGIMES OF A GLACIERIZED BASIN, SLIMS RIVER, YUKON

by
P.G. Johnson[1]

The discharge and suspended-sediment regimes for the Slims River for 1983 and 1988 contrast a glacier melt dominated regime with a storm run-off-dominated regime. The Kaskawulsh Glacier basin is 65% glacierized and normally provides 80% of the flow of the river. The glacier-melt dominated regime peaks in August with discharges in the 250 $m^3 \cdot s^{-1}$ to 350 $m^3 \cdot s^{-1}$ (previously reported) range. Suspended-sediment concentrations are high and variable early in the season as the glacier drainage system is being established and are lower and diurnal later in the season when the drainage system is established. The lower basin is 9% glacierized but instantaneous run-off from large storms can produce flood flows for the river. In 1988 a wet early July superimposed on the snowmelt saturated the basin and high precipitation on the 14th and 15th of July resulted in a peak Slims River discharge of 580 $m^3 \cdot s^{-1}$. Suspended-sediment concentrations were lower during the run-off-dominated period but total loads were very high, with the primary sediment source from the lower basin not from the glacierized component.

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[20]. PULSES IN GLACIER DISCHARGE: INDICATORS OF THE INTERNAL DRAINAGE SYSTEM OF GLACIERS

by
P.G. Johnson[1]

Pulses in discharge measured at the termini of a number of glaciers in the southwest Yukon are similar to "extraordinary" events reported by Hooke (1989) and Rothlisberger and Lang (1987). The pulses are frequent occurrences and can be classified into four hydrograph patterns which can be interpreted as indicators of changes in the internal drainage system of the glaciers. The pulses are concentrated in the spring and early summer when linked conduit and channel drainage networks respond to the increased pressure from the spring melt.

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[21]. DRAINAGE OF AN ICE-DAMMED LAKE, KASKAWULSH GLACIER BASIN, YUKON

by
J. Kasper[1] and P.G. Johnson[2]

Glacier ice-damned lakes have been reported from all glacierized regions. The hazards posed by the catastrophic drainage of these lakes, particularly those located close to the glacier terminus, have been extensively studied. Drainage mechanisms are a combination of ice-margin floatation and thermal erosion of conduits. Many lakes in upper basin areas are not considered hazards but can be significant hydrologically and geomorphologically. A lake along the margin of the Kaskawulsh Glacier, 35 km from the terminus, drains annually. Ice-margin floatation and thermal erosion of the ice conduits are pre-requisites for lake drainage. Initiation of the drainage, however, requires connection to the main conduit system of the Kaskawulsh Glacier. Water-balance figures indicate a substantial and continuous leakage from the lake. Discharge through a 35-km long conduit to the glacier terminus extends the period of drainage to 7 to 10 days compared to the 1 to 2 days for most terminus location lakes.

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[22]. AREAL DISTRIBUTION OF SNOWCOVER IN MOUNTAINOUS AREAS

by
Ånund Killingtveit and Knut Sand[1]

Due to strong wind influence and snow drift, the snowcover in mountainous areas tends to become quite unevenly distributed. The uneven distribution has important implications both for the planning and operation of snow survey networks, and for run-off forecasting by hydrological models. To describe the variability of snowcover a number of statistical parameters are used: areal average, standard deviation, coefficient of variation, spatial-correlation function and areal-distribution function. It is important to realize the variability at the different geographical scales: macroscale, mesoscale and microscale. It is also very important to distinguish between forested and unforested areas. In Norway the statistical parameters for snowcover have been investigated and used in a number of catchments during the last 10-15 years. Guidelines for design and operation of snow surveys are based on information of areal variability and spatial-correlation structure for snowcover in different types of terrain. The areal-distribution function for snowcover is also used directly in the most common precipitation-run-off model, the HBV-model. This model is today in operational use in a number of catchments, mostly by hydro-power utilities. This paper describes briefly the use of statistical snowcover parameters for run-off forecasting and snow-survey planning. The main part of the paper summarizes the results from an extensive data-collection program in a 2655 km² catchment, the Orkla river basin. Characteristic data are given for snow variability in different types of terrain, both above and below the timberline.

The results are given both as statistical parameters and empirical distribution functions, for use in hydrological models.

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[23]. HYDROGEOCHEMICAL ASPECTS OF TWO SELECTED SITES IN A FRINGE ZONE OF DISCONTINUOUS PERMAFROST AND THEIR IMPLICATIONS

by

Y.T. John Kwong, Doug Craig and Michael Griffin[1]

Two sites of about 1 km² each, located in the fringe zone of discontinuous permafrost in northern Alberta, have been instrumented and sampled to study the evolution of water chemistry associated with permafrost degradation. The two sites have similar sediment mineralogy but differ in topography, elevation and the occurrence of permafrost. Isotopic analyses of surface- and ground-waters suggest a common meteoric water source and insignificant, local evaporation effects for both sites. The water chemistry, however, appears to be highly dependent on the thermal regime under which the water-mineral interactions occur. With progressive degradation of permafrost, the aquatic chemistry evolves from calcium-bicarbonate dominated waters to sodium-sulfate type waters. Concurrently, the organic acids content also increases in surface waters. The effect of organic-acid aided mineral weathering associated with climatic warming may have serious implications on water-quality issues and deserve further investigation.

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[24]. ICE COVER GROWTH AND FREEZE-OUT OF SOLUTES IN A MACKENZIE DELTA LAKE

by

Lance Lesack[1], Philip Marsh[1] and Robert E. Hecky[2]

The Mackenzie Delta contains ca. 25,000 lakes and is part of a north-flowing arctic river system where flood water arrives at the delta from the southern portion of the basin before substantial melting of the ice cover on the delta lakes has occurred. As a result, flooding with river water often occurs over the top of the ice on these lakes. The lakes are typically very shallow (mean depth less than 2 m), but despite cold arctic temperatures, ice covers reach a maximum thickness of only 0.6 to 1.2 m. A layer of water commonly remains unfrozen beneath the ice cover, and solute exclusion during growth of the ice and solute remobilization processes can increase solute concentrations within the unfrozen water by several fold. At NRC Lake, water chemistry measurements show that a combination of these processes increased the concentration of the unfrozen lake water by a factor of 4.3 from freeze-up to the time of maximum ice thickness. Profiles of temperature and water density, derived from chemistry measurements, taken during the flood-

ing period indicate that little apparent mixing occurs between the flood water and the denser layer of unfrozen lake water. Despite density differences between the layers of water which are large relative to differences commonly found in holomictic lakes, the lake is sufficiently shallow that the work required to mix the water column to uniform density (stability) is low, and should be readily accomplished by exposure to significant wind. Hence, the presence of a floating ice cover to shield the lake from wind during the flooding period is critical to whether the flood will flush and initialize the lake with river water, or will simply remove the ice and leave the solutes from the previous year in the lake. Virtually all lakes which remain flooded for longer than NRC Lake (about 2/3 of the lakes in the central delta) are flooded sufficiently long that complete mixing of the water column should occur. Many of the remaining lakes probably do not mix with the flood water and flush on every occasion they are flooded. However, ice growth calculations and projected variations in lake geometry indicate that lakes comparable in area to NRC Lake, with a maximum depth of 2.6 to 3.5 m, could lead to sufficiently low water column stability that mixing could occur beneath the ice cover from the shear forces associated with the inflowing and outflowing water movement, and heat contributed by the imported flood water.

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[25]. HYDROLOGICAL PROCESSES IN A SMALL CATCHMENT CONTAINING A PERENNIAL SNOWBANK, MELVILLE ISLAND, N.W.T.

by
Antoni G. Lewkowicz[1] and Kathy L. Young[2]

The hydrological processes operating in a catchment (basin area 0.08 km^2) containing a large perennial snowbank and underlain by permafrost were examined in the summer of 1986. In terms of the basin water balance, the major source was snowbank melt and the major sink, surface run-off. Both of these exceeded 500 mm, making the flux of water through the basin more than double that found in typical basins within the central Canadian Archipelago. The discharge record exhibited the characteristics of a proglacial rather than an arctic-nival regime since a diurnal discharge cycle existed throughout the summer, snowbank melt succeeded basin-wide snowmelt, peak discharge occurred in mid-summer, and daily discharge peaks at the end of summer regularly exceeded those at the beginning. The daily hydrographs changed in shape and timing over the season, becoming more sharply peaked with steeper recessions and exhibiting shorter lag times as the snowbank thinned. Run-off coefficients during small summer precipitation events were similar to the percentage of the basin kept near saturation by continuous outflow from the snowbank, indicating the applicability of the partial area theory of run-off generation to this type of catchment.

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[26]. MAN-INDUCED CHANGES IN THE WATER BALANCE OF NORTHERN RIVER BASINS IN THE FOREST ZONE: THE ESTIMATIONS BY MODELLING RESULTS

by
Yu.G. Motovilov and N.A. Nazarov[1]

A forest basin hydrological model, methods of providing information and verification of the model are considered. The water balance and river run-off component changes are estimated on the basis of numerical experiments for different areas of forest and scenarios of their location in northern regions (case study of the Vologda River basin, area 1270 km^2), northern European part of USSR. Conclusions are derived about the water-protection function of forests during the year.

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[27]. ON MODELLING SURFACE MELTWATER RUN-OFF FROM ARCTIC AND ALPINE GLACIERS

by
D. Scott Munro[1]

An energy-balance model for glacierized basins has been developed in which the microclimate of the glacierized area of the basin interacts with that of the non-glacierized part through horizontal heat exchange. Given the distribution of the winter mass balance, the model proceeds to calculate the summer mass balance and consequent meltwater run-off from the glacier surface. Absorbed global radiation and net longwave loss are the dominant energy controls upon meltwater production, so reduced run-off is the consequence of an increase in either the altitude or the latitude of the glacier. Because other energy exchange terms are important as well, changes in the characteristics on the non-glacierized part of the basin, and climatic change, can be shown to affect melt rates.

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[28]. A HIGH ARCTIC OCCURRENCE OF SEASONAL FROST MOUNDS

by
W.H. Pollard[1]

During 1988 and 1989, 19 frost blisters and 5 icing blisters were documented in the Expedition Fiord area, Axel Heiberg Island, NWT. Frost mounds form each year in the sandy floodplain sediments immediately downslope from a group of mineralized perennial springs on the north side of Expedition River. Discharge occurs from at least 12 to 15 spring outlets near the base of Gypsum Hill. Discharge rates range from 0.2 to 1.4 L·s^{-1}. Each winter

an icing ranging from approximately 30,000 m² to 200,000 m² and up to 2.5 m thick is produced. A group of frost blisters, ranging from 0.9 to 3.5-m high and up to 41-m long, develop in association with the icing. Icing blisters up to 2.5-m high also develop near the spring outlets. Frost blister ice cores 0.4 to 2.0-m thick occur beneath arched bedded fluvial sand. Ice core petrographic and stratigraphic characteristics are consistent with a ground-water injection origin. In some cases, large open cavities within the ice core indicate drainage of the ground-water reservoir before freezing was complete. Chemical analyses of samples from mound ice cores, the icing and spring discharge indicate that the springs are the main source of water for both icing and frost-mound activity. High concentrations of dissolved salts contribute to a freezing temperature depression of spring discharge contributing to perennial spring flow. The study area is located at 79°26'N; 90°46'W at the head of Expedition Fiord, although there are no deep temperature measurements for this area, permafrost is thought to be relatively deep. The occurrence of spring activity has been reported previously; however, this is the first reference to frost mound and icing occurrence in this area. Furthermore, this is the most northern reported occurrence of seasonal frost mound activity, a phenomena usually restricted to discontinuous-permafrost or warmer continuous-permafrost environments.

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[29]. RELATIONSHIPS BETWEEN SNOW CHEMISTRY AND BLOWING SNOW: INITIAL FINDINGS

by

J.W. Pomeroy[1], T.D. Davies[2] and M. Tranter[3]

Measurements of acidic blowing and surface snow in the Cairngorm Mountains of northern Britain indicate profound changes in snow chemistry during wind redistribution of snow. Concentrations of contaminants can be up to three times greater in blowing snow than in eroding surface snow and up to two times greater in accumulating than in eroding snow. Contaminant concentrations in blowing snow increase with height, though contribution from falling snow and recently eroded surface snow can mask this effect and the magnitude of concentration in excess of surface snow values. Sublimation of ice to water vapour during wind transport concentrates the remaining contaminants in blowing snow to a degree which explains much of the observed increase in concentrations, however other ion-specific processes may also affect concentrations. Sublimation of blowing snow may concentrate contaminants in snowpacks over many other windswept areas of the North; further investigations should ascertain the extent and degree of this phenomenon, and its implications for snowmelt chemistry.

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[30]. PEATLANDS OF THE LAKE MELVILLE COASTAL PLAIN, LABRADOR

by
Jonathan S. Price, David Maloney and Fred G. Downey[1]

The peatlands formed on the coastal plain between Lake Melville and the Mealy Mountains represent the largest continuous expanse of wetland in Labrador. They have developed progressively as the coastal plain rises isostatically, with the oldest part of the peatland near the mountain being fen, and more juvenile ombrotrophic bog occurring toward the coast. The water balance of a 2.1 km² basin draining mostly fen and bog, is compared to that of a 3.2 km² mountain basin, and a 0.047 km² section of string bog in the ombrotrophic zone. The mountain portion of the basin has a definite orographic effect, having increased and more frequent rainfall, but the channelized water from the mountain has little interaction with the wetland. The fen peatland section does not readily transmit water along the regional gradient because of its broad expanse and low gradient. The string bog is very effective at storing water because of the storage characteristics of the pools. The peatland water balance indicates that only 10-15% of the inputs are lost as run-off, the remainder occurring as evaporation.

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[31]. ORIGIN OF ACIDITY IN COLOUR LAKE, AXEL HEIBERG ISLAND (79°25'N)

by
S. Schiff[1], M. English[2], R. Elgood[2], M. Hinton[1], M. Ecclestone[3] and L. Pezzutto[2]

Colour Lake is a small acidic lake located in the High Arctic on Axel Heiberg Island. The origin of the exceptionally low water-column pH of this lake (pH 3.7) is of interest in terms of the geochemistry of high-arctic systems and the sensitivity of these systems to change due to global warming. Research on the Colour Lake watershed has been the object of expeditions spanning 3 years and covering snowmelt, late-summer and early-fall periods. Field pH measurements show that the lake is five times more acidic than any of the lake inflows during any of the sampling periods. Hypotheses for the low lake pH include: 1) the seepage into the nearshore areas of the lake of ground water originating at the base of the current frost-free layer in late summer and acid from the weathering of pyrite, 2) in-lake acidification generated by seasonal reduction and oxidation of iron-rich sediments in the small anoxic zone at depth in the centre of the lake, 3) seepage into the lake of deeper, regional acidic ground water, 4) a long water residence time with the acidity still remaining from pyrite oxidized during the initial stages of lake formation following deglaciation. To differentiate between these hypotheses, hydrogeological parameters were measured and water, soil and lake sediment samples were collected for chemical and isotopic analyses.

The lake hydrological budget, constructed from direct gauging of lake inflows and outflows, measurements of ground-water seepage and oxygen isotopes, shows the importance of the melting of the seasonal frost layer to

the hydrological and chemical mass budgets of the lake basin (English et al., 1990, this conference). Sulphur isotopes have been used to constrain both the lake hydrological mass balance and the terrestrial sources of acidity. Sulphur isotopes from the southern portion of the basin and from a nearby set of perennial springs has the typical signature of marine sulphates. Sulphate from the northern portion of the catchment is depleted by 40%, relative to marine sulphate indicating a pyrite source. The lake is a balance between these two endmembers. Porewater samples from the lake sediments show diffusion of reduced iron balanced by sulphate into the lake and the seasonally anoxic hypolimnion has high concentrations of both iron and sulphate. During the 1989 field season, groundwater with a pH as low as 2.71 has been observed seeping into the lake in a small restricted area of the catchment. Hydrogeological measurements and hydrological mass balances are currently being performed to ascertain if one or more of these sources of acidity are sufficient to maintain the acidity of Colour Lake.

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[32]. STUDY OF SURFACE WATER QUALITY IN THE NORTHERN REGION UNDER THE CONDITIONS OF THE POLLUTANT INFLOW INTO WATER BODIES

by
A.N. Shammasov[1]

In northern regions, pollutant inflow into water bodies from open-cut mining has certain specific features:
- clear dependence of the surface water flow on the season of the year;
- dependence of water quality on geochemical properties of the region of flow formation;
- appreciable impact of pollutants on the river water of low salinity;
- influence of nutrients on water bodies eutrophication.

This work is aimed at investigating surface-water quality in phosphate ore extraction with special reference to protection against pollution, selection of water treatment methods, and industrial utilization of treated waste water instead of freshwater. The physical and chemical properties of dissolved and suspended pollutants in the water and seasonal dynamics of its chemical composition were studied, and laboratory experiments were carried out, aiming at decreasing the pollutant concentration.

Surface water from phosphate ore extraction in the Leningrad Region finds its way into the Luga River, which flows into the Gulf of Finland. The river flow during the period of investigation (1981-1985) totalled 28,000 - 47,200 $m^3 \cdot d^{-1}$, the average value being 31,200 $m^3 \cdot d^{-1}$. The water has the following qualitative parameters: pH = 8.1 - 8.35; t° = 2 - 22°C; total hardness = 6.5 - 9.7 $meq \cdot L^{-1}$; phosphate concentration = 0.2 - 5.0 $mg \cdot L^{-1}$; total salinity = 372 - 607 $mg \cdot L^{-1}$; calcium concentration = 2.9 - 4.6 $meq \cdot L^{-1}$; magnesium concentration = 3.6 - 5.1 $meq \cdot L^{-1}$, suspended solids = 244 - 625 $mg \cdot L^{-1}$, etc.

Water sampling data show that the chemical composition of suspensions is determined mainly by silicate compounds (up to 10.1% of their weight) and phosphates (up to 9.01% of P).

The following physical properties of suspended particles were studied:
- density of the particles (1.9 - 2.4 $g \cdot cm^{-3}$);
- surface electric charge (9.8 - 13.1 mV);
- specific surface arem (351 $m^2 \cdot g^{-1}$);
- dispersion composition (5 - 125 μm);
- electrokinetic potential (19.4 mV).

In order to prevent eutrophication, it is necessary to decrease the phosphate content to 0.13 $mg \cdot L^{-1}$. Industrial utilization of purified waste water, instead of freshwater, necessitates a decrease in hardness to 1.8 $meq \cdot L^{-1}$. Seasonal dynamics of phosphates, calcium and magnesium concentration in the water were studied. In spring (March-April) the inflow of the above substances was larger than in other seasons. A special method of water treatment against phosphates and hardness was selected for this period. Our experience shows that water treatment with $CaOH_2$ and NaOH gives the best results.

Dependence of the reduction in hardness on the pH of the water was studied. For pH = 10.5 - 12.0 this dependence can be presented as:

$$H = \exp (21 - 1.83\ pH)$$

where H is the total hardness of the water.

The dependence of the increase in the residual phosphate concentration on the dose of lime (CaO) is as follows:

$$C_{P_2O_5} = 7.31\ D_{CaO}^{-1.39}$$

where $C_{P_2O_5}$ is the residual phosphate concentration in a process of water treatment with a dose of lime.

Therefore, hardness can be regarded as a basic water-quality index for a specially chosen water-treatment method, since its decrease requires more reagents for phosphates elimination. Reduction in hardness can be controlled by measuring the pH value.

Thus the above method of surface water treatment can be recommended for the conditions of increased phosphates concentration in spring.

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[33]. A BASIN WATER STORAGE MODEL TO FORECAST COLUMBIA RIVER DISCHARGE

by
Wendell Tangborn[1]

Seasonal forecasts of unregulated discharge of the Columbia River at the Dalles, Oregon are demonstrated using the HyMet simulation/forecasting model. Forecasts are based solely on the water stored in the basin on the day of the forecast. Water storage is defined as the sum of the snowpack water content, soil moisture and ground water, and is simulated in 6-hour time increments on the basis of observed precipitation and temperature. To select optimum weather stations the model was initially calibrated for the

1950-69 period using daily precipitation observations at thirty National Weather Service cooperative weather stations in or near the Columbia basin. Based on this evaluation, six precipitation stations located in or near the drainage basin were selected and are currently used to represent Columbia basin precipitation. Two temperature stations, one at a low elevation, the other at a high elevation, are used to determine the temperature distribution throughout the basin. Retrospective forecasts for a verification period (1970-88) were produced for each year and each season beginning on January 1 and ending June 1, for seasons ending on July 31, and compared with historic forecasts made by the Northwest River Forecast Center (NWRFC). The HyMet model showed a significant reduction in forecast error for all seasons, with an average decrease in the mean error of the six main forecast seasons of 12.3 to 7.9 percent. The April 1 - July 31 mean forecast error was reduced from 10.2 to 4.8 percent. In addition to a decreased error in seasonal forecasts, the HyMet model provides unlimited forecast frequency and a negligible delay between a weather event and a forecast.

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[3?]. PRELIMINARY FINDINGS ON FORMATION AND EVOLUTION OF FRAZIL AND ANCHOR-ICE UNDER LABORATORY CONDITIONS

by
Gee Tsang[1] and Brian Trapp[2]

Experiments were conducted to study the formation, evolution and other properties of frazil and anchor ice produced in a flume under laboratory conditions. The flume is 1.25 m in diameter, with fixed walls and a rotating bottom. The rotating bottom drags the flow and thus produces a sustained flow in the flume. To a co-ordinate fixed to the rotating bed, the flow is similar to a channel flow. Such an experimental set-up does not interfere with surface heat transfer and the flow behaviour.

The evolution of the two kinds of ice were photographed under polarized light. The concentration of frazil was measured with the frazil instrument that was invented and patented by the author. The flume was placed in a cold room of adjustable temperature. This study is supported by the hydropower industry.

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[35]. LONGITUDINAL DISPERSION IN THE ICE-COVERED ATHABASCA RIVER

by

G. van der Vinne and D. Andres[1]

Little is known about mixing processes in ice-covered rivers. To shed more light on these processes, five separate tracer dye tests were carried out under an ice cover at discharges between 30 $m^3 \cdot s^{-1}$ and 75 $m^3 \cdot s^{-1}$ on the Athabasca River between Hinton and Athabasca. The ice conditions varied significantly, depending on local ice formation processes, with the thickness ranging between 0.5 m and 2.0 m. The mean velocities calculated from the travel times range between 0.26 $m \cdot s^{-1}$ in reaches downstream of Fort Assiniboine where the river slope is as lov as 0.00026, to 0.63 $m \cdot s^{-1}$ for reaches with slopes of 0.00120 in the vicinity of Whitecourt. Transverse mixing was essentially complete for all the test reaches in the narrower upper parts of the river. Downstream of Vega Ferry, however, where the river widens, there were deviations in the peak concentrations across the sections of up to 30% from average. None of the study reaches was found to extend into the Fickian dispersion zone; all the data collected exhibited signs of non-Fickian or linear dispersion. Reach average values of the longitudinal dispersion coefficient (β) were found to vary between 0.0064 and 0.0165. These are higher than those measured in most other rivers with similar hydraulic characteristics but without ice covers. The dispersion model consistently over-estimated the concentrations in the initial portion of the distributions and under-estimated the concentrations in the tails.

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[36]. ECONOMIC IMPACT OF RIVER ICE JAMS IN CANADA

by

G. van der Vinne[1], T.D. Prowse[2] and D. Andres[1]

This paper documents the economic impact of the damage caused by river ice jams across Canada. Most of the damage costs were collected by means of a mail survey although some were obtained from newspapers, journals and reports. The majority of the documented damage occurs in three provinces: Ontario, New Brunswick and Quebec. Only 6% of the total documented damage occurs in the western provinces and the territories. Out-of-channel or floodplain damage costs are much greater than river-structure damage costs. Commercial and residential sectors of the economy are most affected by ice-related floods while bridge damage accounts for 82% of damage to river structures. The total cost of ice-jam damages is at least $766 million and possibly as great as $1.3 billion while the average annual cost of damage over the last ten years was $22 billion.

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[37]. ON COMPUTER SIMULATION OF ICE MOTION IN RIVERS

by
O.G. Vinogradov, A. Springer and P. Wierzba[1]

This paper concerns the phenomenon of ice run and ice jam in rivers. A new approach based on a computer-simulation technique, which allows a quantitative rather than a qualitative description of the problem while at the same time taking into account more parameters governing the phenomenon, is considered. The paper outlines some fundamental results in the area of simulation of multi-body dynamics carried out at the University of Calgary over the last few years, and a potential extension of these results to river-ice mechanics.

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[38]. ESTIMATION OF MASS BALANCE AND RUN-OFF COMPONENT OF URUMQI GLACIER NO.1 FROM WATER BALANCE ANALYSIS

by
Yang Zhenniang[1]

Tianshan Glacier Station is the only comprehensive experimental basin with a complete observation and long-term cold-region record in western China. The area above the hydrological site of Glacier No.1 is 3.34 km², and 58.4% of it is covered by glacier, the elevation is 3693-4486 m. Meteorological and hydrological measurements from 1959-1987 have been used in this paper. Mass balance measurements from stakes are very difficult to obtain so water balance is one of the important methods of estimating glacier mass balance. Water balance analysis of hydrological sites of Glacier No.1 shows that, the mean annual glacier mass balance of Glacier No.1 is about -88 mm and, the run-off components from ice-melt, summer snowmelt, winter snowmelt and firn meltwater are 43.6%, 38.5%, 11.2% and 6.7% respectively.

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[39]. SIMULATION OF RUNOFF IN HIGH AND COLD MOUNTAINOUS REGIONS

by
Yang Zhihuain[1]

The variation of frozen soil in high and cold mountainous regions can affect the distribution of water source and the discharge velocity of ground water. When run-off production begins in spring, the surface water, shallow and deep ground water appear one after another, and the discharge velocity of the ground water also is from quick to slow with the thaw of the frozen soil. So the direct run-off, shallow and deep ground-water run-off also appear successively in basin and the run-off process also trend towards gentleness. After early July, the area and location of each water sources also reached the steady state along with the thawing of frozen soil approach the limit. When calculating the daily run-off process in this kind of basin, firstly determine the distribution of frozen soil in basin according to the date and the elevation; and then determine the supplies for each water sources and the discharge velocity of the ground water; lastly calculate the relevant daily run-off. After through inspection, a better result can be obtained when using this method in small basin of high and cold mountainous regions.

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[40]. PECULIARITIES OF RIVERINE AND LACUSTRINE BIOCENOSES FORMATION UNDER THE CONDITIONS OF HUMAN IMPACT

by
N.S. Zolotareva and M.A. Mordasov[1]

This paper deals with the role of various dimensions of dominating algal types as a factor, ensuring permanent hydrobiocenotic composition under increased anthropogenic loading. It represents a case study of the phytocenosis of the Severnaya Dvina River, its tributaries and lakes of the Solovetsk Islands.

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